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The Financial Implications of Merging Proactive CCTV Monitoring and Directed Police Patrol: A Cost-Benefit Analysis.

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The financial implications of merging proactive CCTV monitoring and directed police patrol: a cost–benefit analysis

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Abstract
Objectives This study presents a cost–benefit analysis of an intervention pairing proactive CCTV monitoring with directed police patrol in Newark, NJ. A recent randomized control trial found that the strategy generated significant crime reductions in treatment areas relative to control areas. The current study focuses on the financial implications of the experimental strategy through a cost–benefit analysis.
Methods The study begins by measuring the costs and benefits associated with the experimental strategy, the findings of which can inform agencies with existing CCTV infrastructure. Follow-up analyses measure the costs and benefits of the intervention for agencies absent existing CCTV infrastructure, meaning a CCTV system would have to be funded in addition to the intervention outputs. Alongside overall benefits, this study presents the tangible cost savings afforded to the Criminal Justice system as well as to each of the separate criminal justice (CJ) system components: Policing, Courts, and Corrections.
Results We found the experimental strategy to be highly cost effective for agencies with existing CCTV infrastructure. However, when the cost of the CCTV system is

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considered, the strategy is largely cost prohibitive. While the cumulative societal and criminal justice findings suggest some evidence of a modest cost savings, the strategy is highly cost prohibitive for each of the individual CJ system components when CCTV system costs are included.
Conclusions Results suggest that the experimental strategy is a worthwhile investment for agencies with existing CCTV infrastructure. Agencies absent CCTV may want to consider whether funds would be better allocated towards alternate strategies.

Keywords Cost–benefit analysis · CCTV · Situational crime prevention · Directed patrol · Policing

Introduction

While the crime prevention capacity of CCTV has recently received increased empirical attention, its cost effectiveness remains largely unknown. With the recent exception of La Vigne et al. (2011), research has not systematically explored the costs of CCTV and whether they are mitigated by the benefits generated from crime reductions. This is important in the current fiscal climate, marked by dwindling public budgets (Wiseman 2011) and claims that CCTV can be used as a force multiplier that simultaneously boosts efficiency and cuts spending (COPS 2011; Cordero 2011). The current study addresses this gap in the literature through a cost–benefit analysis of an intervention that paired proactive CCTV monitoring with directed police patrol in Newark, NJ (hereafter referred to as the CCTV Directed Patrol Strategy; Piza et al. 2015). We begin by measuring the costs and benefits associated with the direct intervention outputs, the findings of which can inform agencies with existing CCTV infrastructure. Further analyses measure the cost effectiveness of the intervention for jurisdictions absent existing CCTV infrastructure, meaning a CCTV system would have to be funded in addition to the intervention outputs. We first calculate the overall costs and benefits, including tangible societal and criminal justice (CJ) costs. We then isolate findings for the criminal justice system as well as the disaggregate system components: Policing, Courts, and Corrections. This allows us to measure the overall cost effectiveness of CCTV while determining whether the financial implications differently affect Policing, Courts, and Corrections systems.

Our findings suggest that the CCTV Directed Patrol Strategy is highly cost effective for agencies with existing CCTV infrastructure. When CCTV system costs are accounted for, very modest cost benefits are found via the Overall and CJ System calculations. However, the strategy is cost prohibitive for each of the individual CJ system components when CCTV costs are considered. This implies that the introduction of human agents, deployed in a proactive manner, in CCTV operations may be a cost-effective way to generate crime reductions. Agencies that need first to invest in a CCTV system, or are unwilling to completely absorb start-up CCTV system costs, are likely to experience a cost deficit with the CCTV Directed Patrol strategy.

Review of relevant literature

CCTV, crime prevention, and cost–benefit analysis

The rise of CCTV as a mainstream crime prevention tool can be traced to the Home Office's *CCTV Challenge,* which provided government funding for the implementation and expansion of CCTV systems throughout the United Kingdom in the mid-1990s. At the time, many scholars lamented the lack of empirical evidence available to determine whether such a large financial commitment was warranted (see, for example, Pease 1999: 53). The time since has seen an increase in the empirical evidence on CCTV. Welsh and Farrington (2002, 2009) conducted two systematic reviews and meta-analyses of CCTV. In addition, a number of program evaluations have been published since (e.g., Cameron et al. 2008; Caplan et al. 2011; King et al. 2008; La Vigne et al. 2011; McLean et al. 2013; Ratcliffe et al. 2009; Reid and Andersen 2014). This body of literature has produced general insights into CCTV, namely that the technology works best in small, well-defined areas (particularly car parks), better deters property crime than violent crime, and is most effective when integrated within proactive crime prevention activities than when deployed as a stand-alone tactic.

The installation of CCTV cameras typically costs millions of dollars (Babwin 2007; Goldstein and Eiserer 2012). Maintenance expenses require similar financial commitment after installation. Ratcliffe and Groff (2011), for example, found that Philadelphia spent US$200,000 a month in maintenance costs, while La Vigne et al. (2011) found that the cost associated with maintaining Chicago's system exceeded the startup costs by the fifth year of the program. Finally, the installation of a CCTV system requires investment in personnel to conduct surveillance-related functions. Chicago reported that their personnel costs ($3,341,000) totaled more than the initial start-up ($1,431,000) and maintenance ($1,713,000) costs combined (La Vigne et al. 2011: 69). Taken together, the expenses associated with CCTV represent a substantial financial commitment. Norris (2003: 256) estimated that CCTV systems have cost over £3 billion in Great Britain over the 10-year period of 1992–2002, not including personnel. While comparable figures are not available for the United States, they are arguably similar given the widespread adoption of CCTV by American police agencies. In the U.S., 49 % of local Police Departments report using public CCTV, with usage increasing to 87 % for agencies serving jurisdictions with populations of 250,000 or more (Reaves 2015).

Because money spent on CCTV could instead be devoted to other strategies, CCTV must demonstrate that it is worth funding over less expensive options. Welsh and Farrington's (2004) systematic review and meta-analysis found that improved street lighting was as equally effective as CCTV in reducing crime. On the one hand, given the lower price tag of improved street lighting, this finding suggests that installing high-performing streetlights may be the wiser of the two investments. On the other hand, benefits realized through CCTV-generated crime reductions could conceivably offset the cost of the system. Because CCTV can provide numerous crime control benefits in addition to crime deterrence (see Ratcliffe 2006), such a finding may support the use of CCTV over improved street lighting despite its higher price tag. Cost–benefit analysis can help policy makers decide between such competing strategies, or determine whether it would be fiscally reasonable to implement both. Unfortunately, situational crime prevention (SCP) evaluations have incorporated cost–benefit analysis far less frequently than other disciplines (Horowitz and Zedlewski 2006; Sherman 2010). Two noteworthy exceptions are particularly relevant to the current discussion. Painter and Farrington (1999, 2001) conducted a cost–benefit analysis of improved street lighting in Dudley and Stroke-on-Trent, UK, finding that the financial savings exceeded the financial costs. La Vigne et al. (2011) conducted a cost–benefit analysis of CCTV in Baltimore and Chicago, USA, finding that in both cities crime reductions generated monetary benefits that exceeded the costs of installing, maintaining, and operating the CCTV system. While these studies separately found both improved street lighting and CCTV as cost beneficial, savings were more pronounced for street lighting, with Painter and Farrington (2001) finding a maximum benefit:cost ratio of 10:1 compared to a maximum of 4.3:1 found by La Vigne et al. (2011). However, because these studies focused on interventions in different countries, we caution against interpreting the findings as more supportive of street lighting. More so, we feel that the novelty of these studies further highlights the need for more cost–benefit analysis of common SCP interventions, as policy makers would benefit from a greater body of research evidence.

Tangible and intangible crime costs: what should be included in a cost–benefit analysis of situational crime prevention?

Prior cost–benefit research has predominately focused on two types of crime costs: tangible costs of crime (e.g., government expenditures on the criminal justice system, lost wages, victims' medical costs) and intangible societal costs of crime (e.g., pain and suffering, fear of crime) (Cohen and Bowles 2010). Traditionally, cost–benefit analysis has stressed the inclusion of all costs associated with a problem (Rice 1966) to ensure that the full spectrum of victimization is reflected in the analysis (Kleiman et al. 2014). However, scholars have recently raised concerns regarding the predominate methods of estimating intangible benefits, specifically willingness-to-pay (WTP) surveys and jury awards for civil damages. The WTP method takes a top–down costing approach by conducting representative surveys of U.S. residents, asking their willingness to vote for a proposal requiring each household in their community to pay between \$25 and \$225 to prevent 1 in 10 of a variety of crime types (Cohen et al. 2004). As noted by Dominguez and Raphael (2015: 616), such an approach assumes that respondents know the actual crime rate and, during the interview, cognitively process a given percentage decline and its implications. Because public perceptions of crime rates are largely inaccurate, with respondents reporting rising crime rates even during years of persistent decreases (McCarthy 2014), WTP estimates are likely biased upwards. A second common source of intangible costs is jury awards in civil damage cases (Cohen 1988; Roman 2009). As noted by Tonry (2015), such lawsuits are typically not against offenders but against wealthy corporations of commercial properties where crimes occurred. Because such cases are not representative of typical victimizations, with most victims lacking the resources to pay attorney fees to pursue civil damages and most crimes not harmful enough to command large awards, they are likely inaccurate and biased upwards (Tonry 2015).

The inclusion of intangible estimates greatly increases the associated cost of a given crime incident. Miller et al. (1996), for example, estimated the cost of crime victimization in 1993 dollars at $105 billion in tangible costs and $450 billion (i.e., over 4 times larger) when intangible costs were included. This directly influences study findings and their policy implications, as “a hypothetical percentage point decline in crime will be perceived as having an impact on crime that is exaggerated relative to true effect” (Dominguez and Raphael 2015: 626). Using as an example commonly reported costs of a single homicide (between $4.8 and $12.4 million) and rape (between $136,000 and $312,000), Tonry (2015: 658) argues that “the benefits of almost any individual prevention program plausibly estimated to have prevented homicides or rapes will exceed costs.” Given these concerns, Dominguez and Raphael (2015: 626) recommend caution in pricing intangible costs, which they identify as “a difficult and poorly defined task,” while Tonry (2015) strongly advocates for eliminating intangible costs altogether from cost–benefit analysis. This approach has been adopted in prior SCP evaluations, with Painter and Farrington (1999: 111) overtly excluding intangible costs due to their “controversial nature.”

Considering the nuances surrounding cost of crime estimates, researchers should first decide upon the specific questions they need answered by the analysis (Kleiman et al. 2014). By framing the analysis in a manner most appropriate for the problem at hand, researchers can help maximize the utility of the study findings. An example of this issue can be drawn from the aforementioned study by La Vigne et al. (2011), to our knowledge the only CCTV evaluation to include a cost–benefit analysis, and recent interpretations of the study’s findings. La Vigne et al. (2011) conducted two versions of their cost–benefit analysis. First, the analysis accounted for both tangible criminal justice costs and intangible societal costs. Second, the cost–benefit analysis excluded societal costs, focusing only on tangible criminal justice costs. As explained by La Vigne et al. (2011), this was done in order to provide a "more relevant ratio from a local financing perspective, as any victimization cost savings that might be attributed to the camera system are not transferred to governments’ budgets"(p. 22). La Vigne et al. (2011) found that, in Chicago, for every $1 spent the system generated $4.30 in savings when both crime and victim costs were considered and $2.81 in savings when only crime costs were considered. Savings were less substantial in Baltimore, where CCTV yielded $1.49 in benefits for every $1 spent when both crime and victim costs were considered. When victimization costs were excluded, the cost of CCTV was roughly equal to the benefit: $1.06 for every $1 spent.

Soon after the La Vigne et al. (2011) study, the Office of Community Oriented Policing Services (COPS) (2011) released a report titled *The Impact of the Economic Downturn on American Police Agencies*. The report argued that police agencies could use CCTV as a force multiplier while also cutting expenditures. This report directly cited the findings of La Vigne et al. (2011), stating "one neighborhood in Chicago alone saw a cost savings of $4.30 for every dollar that was used for the system" (COPS 2011: 26). However, using these figures to advocate for CCTV use by police is questionable for two specific reasons. First, the cost savings of $4.30 includes intangible societal costs, such as diminished quality of life and suffering caused by the victimization. As argued by Ratcliffe (2015: 166) "monetary costs to society mean little to the police as they do not recoup the costs of any crime reduction directly," a main reason why La Vigne et al. (2011) provided two separate cost–benefit estimates.

Second, even the reduced figure of $2.81 exaggerates the benefits police gained from CCTV. In accordance with the general cost of crime literature (Cohen 1988, 1994; Cohen and Piquero 2009), La Vigne et al. (2011: 20–21) included three distinct expenditures in their criminal justice costs: the cost of arrest (Aos et al. 2001), the cost of pre-sentencing (Roman et al. 2008), and the cost of incarceration (Durose and Langan 2004; Roman and Chalfin 2006; Stephan 2004). While the sum of these costs provides a valid measure of criminal justice expenditures, they are not cumulatively absorbed by a single entity. Cost of arrests directly impacts Policing, cost of pre-sentence and adjudication impacts the Courts, and cost of incarceration directly impacts Corrections. Therefore, the cumulative criminal justice cost savings may not demonstrate CCTV to be a cost-effective solution for Policing, simply because Police do not directly benefit from each of these cost categories. It is with these issues in mind that we designed the current study.

Scope of the current study

The current study builds upon the randomized controlled trial (RCT) conducted by Piza et al. (2015) through a cost–benefit analysis. The CCTV Directed Patrol Strategy is well suited for cost–benefit analysis for two main reasons. First, SCP interventions more readily lend themselves to cost–benefit analysis than other tactics because of the relative ease by which cost estimates can be derived, the crime-specific target of such programs, and the easy identification of pre- and post-intervention time periods (Chisholm 2000: 4). Second, the use of an RCT additionally lends confidence to the results, as "the validity of a cost–benefit analysis obviously depends on the quality of the evaluation research design on which it is based" (Painter and Farrington 2001: 3). This also answers recent calls for researchers to more readily translate findings of randomized experiments into financial terms to quantify the costs of particular policy choices (Kuklinski et al. 2015; Sherman 2010).

In deciding upon a specific costing strategy (Kleiman et al. 2014), we considered prior cost–benefit studies as well as the recent commentary by Dominguez and Raphael (2015) and Tonry (2015). First, we limit our measures to tangible costs, following the approach of Painter and Farrington (1999, 2001). Excluding intangible costs avoids the pitfalls described by Dominguez and Raphael (2015) and Tonry (2015) while also producing a more conservative estimate of the achieved benefits. From this perspective, an analysis limited to tangible costs is a more rigorous test of cost effectiveness than one that also includes intangible costs. We follow the approach of La Vigne et al. (2011) by presenting both the overall findings and findings relative to the criminal justice costs. Second, we further account for the fact that, while disparate activities of separate criminal justice system components relate to one another (e.g., an offender arrested by the Police is later processed by the Courts), expenses are not spread evenly across all involved entities. To reflect this reality, we categorized the criminal justice cost savings according to the entity that directly benefits from the averted expenditure. We considered cost of arrest as *Policing Costs*, cost of pre-sentence and adjudication as *Court Costs*, and cost of incarceration as *Corrections Costs*. We are particularly interested in the Policing Costs, as this is the entity most likely to invest in CCTV.

Study setting

CCTV in Newark, NJ

Newark is the largest city in New Jersey, with a population of just over 277,000 residents, spanning over 26 square miles (U.S. Census Bureau 2010). Newark is continuously regarded as a dangerous urban center and, most notably, has historically struggled with issues of serious street-level violence (Tuttle 2009). The Newark Police Department (NPD) recently adopted a number of technological advancements, including the installation of a CCTV system beginning in 2007. CCTV operators monitor camera feeds from the NPD's Video Surveillance Unit (VSU). The operators report detected incidents of concern via the department's Computer-Aided Dispatch (CAD) system. All incidents awaiting dispatch are stored in CAD's *Calls Pending Queue* (along with incidents reported via 9-1-1), with officers dispatched to incidents with higher priority levels before lower priority incidents. This differential response policy is in accordance with accepted standards of police dispatch (LEITSC 2008) and reflects CCTV practices reported elsewhere (e.g., Gill et al. 2005; Lomell 2004; Ratcliffe et al. 2009).

In their evaluation of the first 73 cameras installed in Newark, Caplan et al. (2011) found that auto theft was the only crime type included in the analysis that experienced an overall reduction. However, an analysis of the individual camera locations, rather than the entire CCTV system, found auto theft levels did not change at over half (39 of 73) of the individual camera sites. A replication of the micro-level analysis conducted after the full 146-camera system was in place produced similar results, with auto theft reducing at less than half (54 of 146) of the individual camera sites (Piza et al. 2014a). These evaluations led to a series of follow-up studies meant to better understand the procedural aspects of Newark's CCTV system. These studies found that the presence of *surveillance barriers* prevented the integration of CCTV with proactive police activities. Piza et al. (2014b) found that while crime incidents detected and reported by CCTV operators were closed by on-scene enforcement actions more often than incidents reported via 9-1-1, proactive surveillance activity drastically decreased as the CCTV system expanded. By the time the system expanded to 146 cameras, weekly averages of only 2.11 detections and 1.22 enforcement actions were observed (Piza et al. 2014b). While this suggests that the increasing system size was largely responsible for low levels of activity, the differential response policy of police dispatch likely also played a role. During interviews with researchers (Piza et al. 2014c: 12), Newark's CCTV operators "overwhelmingly reported that aspects of police dispatch—specifically large queue times—discouraged them from reporting" many of the criminal infractions they observed. Piza et al. (2015: 49) observed that, "If proactive enforcement is truly related to CCTV's deterrent effects, this prior research may explain the lack of a significant, widespread effect in Newark."

The Newark Police Department's CCTV directed patrol strategy (Piza et al. 2015)

The aforementioned studies were followed by an RCT that sought to overcome the high camera-to-operator ratio and the differential response deployment of officers via the *calls-pending queue*. During all experimental tours of duty, one additional CCTV operator was deployed to the control room and exclusively dedicated to monitoring the target areas. In addition, two unmarked patrol units were deployed to the target areas to respond to incidents detected by the experimental operators. Instead of the standard practice of reporting criminal activity through the department's CAD system, the experimental operator reported crime detections directly to the field units via two-way radio. The experiment incorporated a randomized block design, with 38 CCTV schemes (encompassing 64 individual cameras) assigned to either the treatment or control group. [1] These 38 schemes were matched into pairs based on their level of three types of calls-for-service: violent crime, social disorder, and narcotics activity.[2]

The CCTV Directed Patrol strategy took place during the 11-week period from 7/20/2011 to 10/01/2011. The experiment was designed to run 4 days a week, Wednesday through Saturday, from 8 pm to 12 am to reflect the days and times at which the crimes of interest were at their height during the previous year. In recognition of prior research demonstrating that temporally focused police interventions may produce deterrent effects lasting a longer time frame (Sherman 1990; Telep et al. 2014; Wyant et al. 2012), outcomes were measured across three distinct time periods: tours of duty (Wednesday through Saturday, 8 pm to 12 am, 7/20/2011–10/01/2011), days (24-h period or each day the experiment ran), and the entire 11-week period (7/20/2011–10/01/2011). Using three time periods also represented a pseudo-sensitivity analysis, ensuring that the results were not merely the by-product of a single temporal parameter. In addition to the during-experiment period, experiment effect was measured for the post-experiment period (10/05/2011–12/17/2011) to determine whether program effects extended beyond the experiment period.

Piza et al. (2015) found that the CCTV Directed Patrol strategy generated significant crime prevention benefits in the treatment areas relative to the control areas (see Table 1). In the during-experiment period, statistically significant crime reductions (noted by IRR < 1) were observed in four instances. In addition, narcotics activity experienced a statistically significant reduction during the post-experiment period. Weighted Displacement Quotients (WDQs) measure the presence of any displacement (negative values) or diffusion of benefits (positive values). The Total Net Effect (TNE) combines the target area reduction and spatial displacement/diffusion effects into an estimate of the number of crimes prevented (or generated) by the intervention. For each time period, the cumulative values suggest a crime reduction.

Methodology

In conducting this cost–benefit analysis, we began by creating confidence intervals for the TNE values reported by Piza et al. (2015). La Vigne et al. (2011) measured the statistical significance of cost–benefits by monetizing the 95 % confidence bounds of their statistical models. Both the lower and upper bounds were multiplied by the estimated cost of crime to allow for assessment of statistical significance. La Vigne et al. (2011: 123–130) repeated this process twice: once for the difference-in-

[1] For more information on the unit of analysis operationalization, see Piza et al. (2015: 50–51).

[2] These specific crime types were selected for the evaluation in recognition of previous research finding CCTV effect to be greatest on automobile crime in car parks and limited in public places, specifically against such street-level activity as the aforementioned crimes (Caplan et al. 2011; Phillips 1999; Welsh and Farrington 2002, 2009).

Table 1 CCTV patrol experiment effect (Piza et al. 2015)

Time period	IRR during (95 % CI)	WDQ during	IRR post (95 % CI)	WDQ post	TNE (95 % CI)
Violent crime					
Tours	0.52 (0.27; 0.98)	0.46	n.s.	n.a.	−58 (−48; −76)
Days	0.60 (0.37; 0.99)	−0.06	n.s.	n.a.	−47 (−36; −67)
11 weeks	n.s.	n.a.	n.s.	n.a.	n.a.
Social disorder					
Tours	0.51 (0.27; 0.97)	−1.09	n.s.	n.a.	3 (−14; 16)
Days	n.s.	n.a.	n.s.	n.a.	n.a.
11 weeks	0.59 (0.37; 0.93)	1.34	n.s.	n.a.	−189 (−63; −217)
Narcotics activity					
Tours	n.s.	n.a.	n.s.	n.a.	n.a.
Days	n.s.	n.a.	0.51 (0.24; 1.06)	−1.24	3 (−5; 8)
11 weeks	n.s.	n.a.	n.s.	n.a.	n.a.

The IRR for Narcotics activity during the post-experiment days period was significant at the 90 % level. Given the underpowered nature of the experiment, this was considered as statistically significant by Piza et al. (2015). For consistency, we also consider this a significant reduction for the cost–benefit analysis

IRR Incident Rate Ratio; *WDQ* weighted displacement quotient; *TNE* total net effect; *n.s.* not significant; *n.a.* not applicable

difference models measuring crime changes in the target areas and once for models measuring the buffer (displacement) areas.

Creating confidence bounds for the effect estimates of Piza et al. (2015) necessitated an alternate process due to the different statistical approach. Piza et al. (2015) first measured the intervention effect in the target area via negative binomial regression models. Intervention effect was reported via the Incident Rate Ratio (IRR), interpreted as the rate at which the dependent variable is observed, with a value of 1 as the baseline (e.g., an IRR of 0.90 suggests a 10 % decrease in the dependent variable; Braga and Bond 2008: 590). For all crime types exhibiting statistically significant IRR values suggestive of a crime reduction (i.e. below 1), pre-, during-, and post-intervention crime counts were used to calculate the TNE. The TNE estimates the cumulative number of crimes prevented or generated by the intervention by simultaneously accounting for observed crime changes in the target, displacement, and control zones (Ratcliffe and Breen 2008). TNE is calculated via the formula:

$$TNE = \left[Rb\left(Ca/Cb\right) - Ra\right] + \left[Db\left(Ca/Cb\right) - Da\right]$$

where R, C, and D represent the target, control, and displacement zones, respectively, b represents the time period before the intervention, and a represents the period during the intervention (Guerette 2009: 41). The first part of the formula shows the crime level changes in the target area as compared to the control area, which is analogous to the IRR of the negative binomial regression models. To account for the uncertainty of the point estimates, we applied the observed confidence intervals of IRRs to create lower and upper bound estimates for the TNE. For each observed crime reduction, the upper and lower bounds were first subtracted from the IRR to measure the range of effect. Because the IRR reports percent change in incident counts, subtracting the confidence bounds shows the percentage by which the estimates should be adjusted for uncertainty. For example, violent crime during the *tours* period exhibited an IRR of 0.52 with a 95 % CI of 0.27–0.98. The lower bound of the CI is 25 % smaller than the IRR (0.27 – 0.52 = −0.25) while the upper bound is 46 % larger (0.98 – 0.52 = 0.46). Hence, the first part of the TNE formula was first decreased by 25 % and then increased by 46 % in order to create the lower and upper bound estimates for the total crime incidents generated or prevented by the intervention. This process was repeated for each statistically significant crime reduction. TNE confidence bounds are presented in the final column of Table 1.

Measuring costs of crime and benefits of crimes prevented

Table 2 displays the cost of all crime types included in this study. In calculating crime costs, we adapted figures presented by La Vigne et al. (2011: 22, table 3.10) and McCollister et al. (2010: 104, table 3). Figures provided in 2009 dollars by La Vigne et al. (2011) and 2008 dollars by McCollister et al. (2010) were converted into 2011 dollars via the Bureau of Labor Statistics' Consumer Price Index Inflation calculator.[3] This conversion method follows the approach of McCollister et al. (2010).

We used cost estimates of La Vigne et al. (2011) to measure criminal justice costs. These estimates were compiled from a series of studies that updated the cost estimates of Cohen (1994) (i.e. Aos et al. 2001; Durose and Langan 2004; Roman and Chalfin 2006; Roman et al. 1998; Stephan 2004). La Vigne et al. (2011) provided a breakdown of the CJ costs according to the precise type of expenditure: cost of arrests (Policing Costs), cost of pre-sentence and adjudication (Court Costs), and cost of incarceration (Corrections Costs). Because La Vigne et al.'s (2011) estimates of Victim Costs included intangible expenses, we used the estimates of McCollister et al. (2010), the only study to disaggregate tangible and intangible victim costs according to a systematic review of cost–benefit research (Wickramasekera et al. 2015).[4]

Costs of social disorder and certain violent crime categories used in the current study were not estimated in the extant literature. Because the crimes included in the social disorder category were the least serious in the current study, the lowest estimated cost was selected for these incidents. None of the referenced studies provided cost estimates for shootings, stabbings, or fights, which are unique categories of assault. Rather, costs were distinguished between *aggravated assault* and *simple assault*. Fights were

[3] http://www.bls.gov/data/inflation_calculator.htm. All other cost estimates included in this study were converted via this same method.

[4] McCollister et al. (2010) did not provide any cost estimates for social disorder, drug offenses, or weapon possession due to their status as "victimless crimes." Therefore, for these crime categories, we used the cost estimates provided by La Vigne et al. (2011). While these estimates include intangible costs, we consider this discrepancy as inconsequential given the very low costs ($221.49 for social disorder, $39.70 for drug offenses, and $281.04 for weapon possession).

Table 2 Cost of crime incidents

Crime category	Overall costs[a]	Victim costs[b]	CJ system costs[c]	Policing costs	Court costs	Corrections costs
Social disorder[d]	$7,773.74	$221.49	$7,552.25	$2,804.70	$3,816.49	$931.06
Drug offenses	$13,023.10	$39.70	$12,983.40	$2,804.70	$9,132.31	$1,046.39
Violent crime (median)	$41,761.79	$7,907.76	$34,574.86	$18,625.30	$9,132.31	$6,817.25
Aggravated assault	$43,664.23	$9,089.37	$34,574.86	$18,625.30	$9,132.31	$6,817.25
Fight[e]	$39,859.34	$6,726.14	$34,574.86	$18,625.30	$9,132.31	$6,817.25
Robbery	$38,791.10	$3,446.65	$33,133.20	$18,625.30	$9,132.31	$5,375.59
Shooting[e]	$43,664.23	$9,089.37	$35,344.45	$18,625.30	$9,132.31	$7,586.84
Stabbing[e]	$43,664.23	$9,089.37	$34,574.86	$18,625.30	$9,132.31	$6,817.25
Weapon possession	$33,414.24	$281.04	$34,574.86	$18,625.30	$9,132.31	$6,817.25

[a] All costs displayed in this table were converted into 2011 dollars via the Bureau of Justice Statistics' Consumer Price Index Inflation calculator (http://www.bls.gov/data/inflation_calculator.htm)

[b] Victim costs were primarily collected from table 3 of McCollister et al. (2010: 104). McCollister et al. (2010) did not provide any cost estimates for social disorder, drug offenses, or weapon possession given their status as "victimless crimes." Therefore, for these crime categories, we used the cost estimates provided by La Vigne et al. (2011)

[c] Criminal Justice costs were calculated from table 3.10 of La Vigne et al. (2011: 22). Policing costs are considered the cost of arrest. Court costs are considered the cost of pre-sentencing and adjudication. Corrections costs are considered cost of incarceration. The total CJ costs are a summation of these three values

[d] None of the referenced costs-of-crime studies provided cost estimates for social disorder. Therefore, the costs of the social disorder category were estimated using costs of the other categories. Because the crimes included in the social disorder category were the least serious in the study (i.e. drinking in public, panhandling, etc.) the lowest cost of each cost category estimated by La Vigne et al. (2011) was selected

[e] None of the referenced costs-of-crime studies provided cost estimates for shootings, stabbings, or fights, unique categories of assault. Rather, costs are distinguished between "aggravated assault" and "simple assault." Therefore, fights were assigned the costs of "simple assault" to reflect their less serious nature. Shootings and stabbings were assigned the costs of "aggravated assault"

assigned the costs of *simple assault* to reflect their less serious nature. Shootings and stabbings were assigned the costs of *aggravated assault*.[5]

The extant literature assigns cost values to individual crime types that comprise the violent crime category in the current study. For the Policing and Court categories, the costs were identical for each of the crime types. The Corrections and CJ System costs differed across crime types. Therefore, the median value of the violent crime types was used as the metric by which crime reduction savings were determined for Corrections ($6,830.25), as well as the CJ System costs ($34,627.95). This approach avoids the extreme (and likely unrealistic) estimates that would result from using either the

[5] It should be noted that this likely underestimates the true costs of shootings and stabbings, and consequently the cost–benefit of the intervention, since these incidents may pose a high risk of fatality to the victim. Furthermore, while no crime incidents during the pre- or post-periods were classified as homicide, this is likely due to the use of calls-for-service data, as callers likely did not have knowledge of the victim's status. Callers are likely to report the occurrence of a shooting or stabbing incident rather than the death of a victim, even in instances that the victim died.

minimum or maximum violent crime cost and is a more conservative estimate than the mean.

The TNE figures discussed in the previous section were used to calculate the monetary benefits of the observed crime reductions. Given that TNE values were reported for three separate time periods (tours, days, and 11 weeks), benefits were calculated for each distinct period as well. Each TNE was multiplied by the cost associated with each crime category to determine cost savings (see Table 3).To account for uncertainty in the estimates, costs were also multiplied for the lower and upper bound TNE estimates. This generated confidence intervals used to measure the statistical significance of the monetary benefits.

Measuring costs of the intervention

Cost–benefit analysis is concerned with two basic components: inputs, the resources expended in the implementation of an intervention, and outcomes, the consequences of the intervention. Inputs are the *additional* human, physical or financial resources used in a project, separate from elements that would have occurred anyway in the absence of the intervention (Dhiri and Brand 1999: 12). When strictly adhering to this definition, the inputs of the CCTV Directed Patrol strategy can be separated into two categories: personnel costs and vehicle costs (see Table 4A).

During each tour-of-duty, five additional officers were dedicated to the CCTV operation: one video surveillance operator, three patrol officers, and one patrol supervisor. The experiment was designed for each tour to last 4 hours, from 8:00 pm through 12:00 am. However, enforcement activities often led to personnel working more than 4 hours. When an arrest occurred towards the end of a tour, officers and CCTV operators stayed past the scheduled end time to process the arrest and export/submit video footage as evidence, respectively. The precise number of hours each officer worked was measured from his or her log sheet, submitted at the end of each tour. Over the experiment, CCTV operators worked 167 hours, patrol supervisors worked 168 hours, and patrol officers worked 500.5 hours. The NPD conducted the experiment on an overtime basis, with personnel participating outside of their everyday assignments. Therefore, overtime hourly wages were used to calculate the personnel expenditures. The three patrol officers and the one CCTV operator were paid the police officer wage of $85.26 an hour, which includes fringe benefits.[6] Patrol Supervisor costs varied because officers of various ranks, each with different hourly wages, were assigned as Patrol Supervisors throughout the experiment.[7] The hourly wages, including fringe benefits, for each supervisor rank are as follows: Captain, $118.31; Lieutenant, $103.86; Sergeant, $96.41. Personnel costs totaled $73,647.56.[8]

[6] All hourly wages include a fringe benefit of 35.5 %. Fringe rates for individual NPD officers range from 33 % to 38 % due to the variety of benefits packages offered to employees. Therefore, we used 35.5 % since it is the median value between these two extremes.

[7] Officer ranks were determined from the log sheets.

[8] We acknowledge that future implementations of the CCTV Directed Patrol strategy (in Newark or elsewhere) could involve personnel working during their regularly scheduled tours of duty, meaning that they would not be paid at the higher overtime rate. Using the regular hourly wages, rather than overtime wages, did not alter the findings of the study. For the interested party, cost calculations and findings incorporating the alternate regular wage calculations can be obtained from the lead author.

Table 3 Total net effects and associated cost savings

Crime category	Tours	Days	11 weeks
Social disorder			
TNE	3 (−14; 16)	0	−189 (−63; −217)
Overall cost savings	−$23 K (108 K)	$0	$1.5 M ($490 K; $1.7 M)
CJ cost savings	−$23 K (105 K)	$0	$1.4 M ($475 K; $1.6 M)
Policing cost savings	−$8 K (−$45 K; $39 K)	$0	$530 K ($177 K; $609 K)
Courts cost savings	−$11 K (53 K)	$0	$721 K ($240 K; $828 K)
Corrections cost cavings	−$3 K (13 K)	$0	$176 K ($59 K; $202 K)
Narcotics activity			
TNE	0	3 (−5; 8)	0
Overall cost savings	$0	−$39 K (−$104 K; $65 K)	$0
CJ cost savings	$0	−$31 K (−$81 K; $51 K)	$0
Policing cost savings	$0	−$8 K (−$22 K; $14 K)	$0
Courts cost savings	$0	−$27 K (−$73 K; $46 K)	$0
Corrections cost savings	$0	−$3 K (−$8 K; $5 K)	$0
Violent crime			
TNE	−58 (−48; −76)	−47 (−36; −67)	0
Overall cost savings	$2.4 M ($2 M; $3.2 M)	$1.9 M ($1.5 M; $2.8 M)	$0
CJ cost savings	$2 M ($1.7 M; $2.6 M)	$1.6 M ($1.2 M; $2.3 M)	$0
Policing cost savings	$1 M ($894 K; $1.4 M)	$875 K ($671 K; $1.3 M)	$0
Courts cost savings	$530 K ($438 K; $694 K)	$429 K ($329 K; $612 K)	$0
Corrections cost cavings	$395 K ($327 K; $518 K)	$320 K ($245 K; $612 K)	$0
Cost savings sums			
Overall cost savings	$2.1 M ($1.8 M; $2.7 M)	$1.7 M ($1.2 M; $2.5 M)	$1.3 M (435 K; $1.5 M)
CJ cost savings	$1.9 M ($1.8 M; $2.5 M)	$1.6 M ($1.1 M; $2.4 M)	$1.4 M ($476 K; $1.6 M)
Policing cost savings	$1 M ($933 K; $1.4 M)	$867 K ($648 K; $1.26 M)	$530 K ($177 K; $609 K)
Courts cost savings	$518 K ($492 K; $633 K)	$402 K ($256 K; $658 K)	$721 K ($240 K; $828 K)
Corrections cost savings	$393 K ($340 K; $503 K)	$317 K ($237 K; $462 K)	$176 K ($59 K $202 K)

Lower and upper bound estimates presented in parentheses. Cost savings are approximate due to rounding.

Vehicle costs included two separate calculations. First, we estimated the expenses associated with the general operation of the two patrol units. While a vehicle's total usage is positively correlated with maintenance expenses (Lauria 2007), the cost associated with a *single tour-of-duty* is elusive. After consulting with NPD officials,

Table 4 Costs of intervention inputs and CCTV system

A. Intervention inputs		B. CCTV system	
Personnel	OT cost	Cameras and wireless network[h]	
Total	$73,647.56	Total	$1,165,942.10
CCTV operator	$14,237.85	Start-up costs	$1,019,180.16
Working hours	167.0	Cost per camera	$31,849.38[i]
Hourly wage[a]	$85.26	Total cameras	32
Patrol supervisor	$16,738.38	Maintenance costs	$146,761.94[j]
Working hours	168.0		
Hourly wage[b]	$96.41 – $118.31		
Patrol officers	$42,670.93		
Working hours	500.50		
Hourly wage	$85.26		
Vehicle expenses	Cost	Video surveillance unit personnel[k]	
Total	$2,185.81	Total	$73,394.08
Maintenance costs	$1,200.00	Unit commander	$26,510.41
Per-tour vehicle fee[c]	$15.00	11 week salary	$19,564.88
Vehicles per tour	2	35.5 % fringe rate	$6,945.53
Number of tours	40	CCTV operators	$46,883.68
Fuel costs	$1,025.51	11 week salary	$17,300.25
Vehicle driving minutes[d]	13,631.000	35.5 % fringe rate	$6,141.59
Vehicle miles driven[e]	4,537.670	Number of operators	2
Gallons of fuel consumed[f]	283.604		
Fuel cost per gallon[g]	$3.616		
Total intervention costs		Total system costs	
$75,873.07		$1,239,336.18	

[a] The hourly wage for all personnel is at the 1.5 overtime rate and includes a fringe benefit of 35.5 %

[b] The overtime hourly wages for each Patrol Supervisor rank are as follows: Captain, $118.31; Lieutenant, $103.86; Sergeant, $96.41

[c] This cost reflects the Newark Police Department's Outside Employment Unit's daily vehicle fee of $15

[d] Vehicle driving minutes estimated from observational data collected within the CCTV control room

[e] Assumes that officers drove at a speed of 20 miles per hour throughout the tours

[f] U.S. Department of Energy (www.fueleconomy.gov)

[g] U.S. Energy Information Administration (www.eia.gov)

[h] All CCTV-related expenses were converted to 2011 dollars

[i] The per-camera installation costs were based upon a $3.2 million grant from the Newark Community Foundation in 2007, which directly funded the hardware, camera mounting, network connectivity, and software configuration for 109 individual camera sites

[j] Estimated at 14.4 % of initial start-up costs, as observed in the comparable system of Baltimore, MD (La Vigne et al. 2011)

[k] The personnel costs relate only to the portion of the salaries that would be paid over an 11-week period, to reflect the experiment period. The yearly salaries and 35.5 % fringe rate for the Unit Commander ($125,321.92) and each CCTV Operator ($81,783) were divided by 52 to determine the weekly salary amount. This weekly amount was then multiplied by 11 to determine the experiment period salary

we determined that the cost of vehicle deployment should match the department's vehicle fee schedule, as determined by the Outside Employment Unit (OEU). OEU works with outside entities requesting police presence for non-NPD related events, such as directing traffic at construction sites or providing crowd control at outdoor events. As part of this function, OEU charges a fee of $15 per police vehicle for each event, which is allocated towards vehicle maintenance and repairs. We estimate the cost of vehicle operation as $15 per patrol car, totaling $30 per tour and $1,200 for the experiment.

Second, fuel costs were calculated from two separate measures: per-gallon cost of fuel and gallons of fuel consumed. Fuel costs were estimated at $3.616 per gallon, the average weekly price of fuel in the East Coast (including New Jersey) over the 11-week study period, as reported by the U.S. Energy Information Administration.[9, 10] Estimating gallons of fuel consumed required a multi-step process. We first estimated the number of miles driven by consulting the field notes of researchers present within the CCTV control room during each experiment tour. Researchers monitored officer response via the CCTV cameras and noted the number of minutes officers were stationary at the scene. Researchers also measured the amount of time that officers spent processing arrests.[11] The sum of the *on-scene* and *arrest process* times represented the total minutes that police were out-of-service and not driving. This time was subtracted from the total length of the tour to estimate the number of minutes officers drove. We estimated that the officers drove a total of 13,631 minutes totaling 4,537.60 miles driven.[12] Fuel consumption was measured by dividing this mileage by 16 to reflect the miles per gallon of the specific vehicle used by the officers (Ford Crown Victoria) as reported by the U.S. Department of Energy.[13] We estimated the consumption of 283.604 gallons of fuel during the experiment. At $3.616 per gallon, this translates to a fuel cost of $1,025.51.

Measuring costs of a CCTV system

As previously discussed, inputs include *additional* resources introduced by the intervention (Dhiri and Brand 1999). Given that the CCTV system was in place at the time

[9] http://www.eia.gov/petroleum/gasdiesel

[10] Fuel prices are not uniform throughout the year, but fluctuate according to seasonal variations in supply and demand. Therefore, fuel costs may have significantly differed if the RCT were conducted at a different time of the year, or extended for a longer period of time. Impact to the current study is minimal, as fuel costs ($1,025.51) represent only approximately 1 % of the existing system expenses and a fraction of a percent in the non-existing system expenses. Nonetheless, the reader should be mindful of the potential impact variable fuel costs can have in cost–benefit analysis particularly when fuel costs comprise a larger percentage of expenditures.

[11] After each arrest, the officers transported all arrestees to the nearest police precinct for processing. While at the precinct, officers used the department's Records Management System (RMS) to complete all necessary reports and a background check for the arrestees. RMS captures the time an officer logs on and submits final reports for an arrest. The sum of the minutes between these two time periods was considered the *arrest process* time.

[12] This assumed an average driving speed of 20 miles per hour. The speed limit on local roads (which primarily comprised the target areas of the experiment) in Newark is 25 miles per hour. We used an estimated speed of 20 miles per hour to account for the periodic slowdowns (e.g. traffic) or stoppages (e.g. waiting at a red light) that the patrol cars encountered.

[13] http://www.fueleconomy.gov/feg/Find.do?action=sbs&id=30683&id=29326&id=26232&id=24159

of the experiment, it did not represent an input in the strict sense of the term. However, because research has demonstrated the effect of stand-alone CCTV deployment as limited, agencies considering the deployment of CCTV may not do so without also assigning personnel to proactively address incidents of concern, in a manner similar to the CCTV Directed Patrol strategy. Indeed, successful CCTV programs have reported police units working closely with CCTV operators to proactively detect and directly address street-level incidents of concern (see the chapters on the Baltimore Police Department in La Vigne et al. 2011). Furthermore, agencies that allocated funds to the installation and maintenance of cameras may be unwilling to ignore these expenses when evaluating CCTV-related interventions, even those enacted well after the installation of cameras.

Table 4B displays the cost of the CCTV system. Donations and grant funding provided to the Newark Police Foundation, the fundraising arm of the NPD, paid for the installation of the CCTV system. The bulk of the funding came from a $3.2 million grant from the Newark Community Foundation in 2007. This grant directly funded the hardware, camera mounting, network connectivity, and software configuration for the first 109 camera sites. Therefore, we estimated the cost associated with installing a single camera in 2007 as $29,357.80 ($3.2 million/109), which translates to $31,849.38 in 2011 dollars. With 32 cameras in the experiment target area, we estimated the installation cost as $1,019,180.16

In addition to installation costs, CCTV systems have recurring maintenance costs, such as software upgrades and hardware repairs. The NPD did not purchase a maintenance contract for their system and did not keep readily accessible records of their maintenance expenses. Therefore, we consulted La Vigne et al. (2011) in estimating maintenance costs. The systems studied by La Vigne et al. (2011), and their associated recurring costs, were very divergent. Chicago's system included approximately 8,000 cameras, about 6,000 of which were owned and operated by outside entities (i.e. private businesses and citizens). Chicago's system streams live footage from all cameras to computers connected to its network, enabling all officers to view CCTV footage from their desktop monitors, a configuration unique to Chicago (La Vigne et al. 2011: 54–55). Conversely, Baltimore operates approximately 500 cameras, all owned and operated by the Baltimore PD, with video feeds visible from a single control room (La Vigne et al. 2011: p. 23). Because this configuration is more representative of typical police-led CCTV systems, including NPD's, we used Baltimore's maintenance costs as guidance. Baltimore's maintenance costs ($775,000) were 14.4 % of their initial start-up costs ($5,479,000) (La Vigne et al. 2011: 47). We estimated NPD's maintenance costs at 14.4 % of the start-up costs, totaling $146,761.94.

In addition to the staff dedicated to the CCTV Directed Patrol strategy, additional officers are needed to fulfill day-to-day functions. CCTV operations involve a host of activities, including reviewing past footage, monitoring cameras in response to citizen calls-for-service (as opposed to the proactive monitoring activities conducted in the experiment), burning disks at the request of outside parties, completing administrative reports, fielding telephone calls, and operating complimentary technologies, such as Gun Shot Detection Systems (Gill et al. 2005; Keval and Sasse 2010; Leman-Langlois 2002; Piza et al. 2014b). It is important to distinguish between such day-to-day tasks associated with the general CCTV system and the proactive monitoring practices of the

CCTV Directed Patrol strategy, divergent activities dependent on the efforts of separate personnel. Such day-to-day personnel expenses were estimated to reflect VSU's staffing configuration at the time of the experiment, which consisted of two operators and one sergeant. The operators cover two different 8-hour shifts, one from 11 am through 7 pm and another from 7 pm through 3 am. The yearly salary of the officers is $81,783.00, plus a fringe of $29,032.97. The sergeant works a shift from 9 am through 5 pm at a yearly salary of $92,488.50 plus a fringe of $32,833.42. To reflect the study period, we calculated the amount of salary paid to the personnel over an 11-week period. We first divided the salaries by 52 to determine the weekly salary amount. This amount was then multiplied by 11 to determine the experiment period salary. The VSU personnel salary totaled $73,394.08.[14]

Calculating program benefits: cost–benefit ratios (CBR)

A Cost–Benefit Ratio (CBR) is the monetary benefit of the intervention divided by the cost of the intervention (Bowers et al. 2004: 297). We calculated the CBR via the formula:

$$CBR = B/C$$

where B is the monetary benefit of the crime reduction and C is the cost of the intervention inputs. Interpretation of the CBR is straightforward, with values above 1 indicating that the intervention was cost beneficial and values below one suggesting that it was cost prohibitive (Bowers et al. 2004). Five CBRs were calculated, one for each component of interest: Overall Savings, CJ System, Policing, Courts, and Corrections. To inform agencies absent CCTV systems, an alternate CBR was calculated where the cost of installing, maintaining, and operating a CCTV system was included in the formula.

To account for the delay in program benefits, we applied a discounting rate (D_n) to the numerator of the CBR formula. Discounting has commonly been used in cost–benefit analysis, including evaluations of SCP efforts (Painter and Farrington 1999, 2001). Discounting was unnecessary in the existing system analysis, because the personnel and vehicle costs were all allocated during the same year as the achieved benefits (2011). We discounted benefits in the non-existing system calculations since the installation of Newark's CCTV system occurred in 2007, 4 years before the RCT. We used the discounting formula commonly used in criminal justice (Dhiri and Brand 1999) as well as other public policy research (Howard 2013; Kolb and Scheraga 1990; Weimer 2008):

$$D_n = 1/(1+r)^n$$

[14] These salaries represent the top salary-step of NPD patrol officers and sergeants, respectively. This salary-step was used to reflect the structure of the NPD in 2011. In November 2010, budget constraints led the city to lay off 167 officers (Star Ledger 2010). This represented over 13 % of the agency, virtually all junior-level officers. The remaining officers were senior-level, with salaries at or near the top salary-step.

where r is the annual discount rate and n represent the number of years between the program start date (in this case, the installation of CCTV) and the realization of cost benefits. We used a time period of 4 years to reflect the time between the CCTV system installation and deployment of the CCTV Directed Patrol strategy. We used a yearly discount rate of 3 %, which Cohen and Bowles (2010: p. 146) identify as the standard rate used in U.S.-based economics research.

We concluded with a sensitivity analysis meant to "indicate the range of values within which assumptions can be safely ignored or the specific conditions that must be found or produced if a policy or program is to yield the desired result" (Barnett and Escobar 1987: 391). Sensitivity analysis is an important step in any cost–benefit analysis since it ensures the rigor of the findings against a range of alternate assumptions (Chisholm 2000; Dhiri and Brand 1999; Welsh et al. 2013). In the current study, we presented alternate assumptions for the officer wages and CCTV System, which jointly accounted for the vast majority of the intervention expenses. Data from the Bureau of Labor Statistics (BLS) (2015) were used to operationalize alternate officer wages. According to BLS (2015), New Jersey has the highest mean wage of Police and Sherriff's officers in the U.S. with Newark officer wages ranking in the 90th percentile. We recalculated program benefits using officer wages from the 75th and 50th percentiles to provide estimates for police departments in states more representative of national salaries.[15] We were unable to find national estimates for CCTV camera costs, so we recalculated benefits with CCTV system expenses both decreased and increased by 25 %. These adjustments were used for both the existing system and the non-existing system CBRs.

Findings

Table 5 displays the CBR values. In each of the existing system calculations, the intervention was cost beneficial. Statistically significant CBRs ranged from 19.36 to 31.62 in the Overall calculations, from 18.81 to 26.13 for the CJ System, from 6.99 to 14.13 for Policing, from 5.30 to 9.51 for Courts, and from 4.18 to 5.18 for Corrections. This provides strong support for the cost benefit of the CCTV Directed Patrol strategy, as the direct costs of the intervention inputs were completely offset by the benefits generated by the crime reduction. The benefits were not restricted to any particular component, with all CBRs suggesting significant cost savings. CBRs associated with a non-existing system, meaning the costs of implementing CCTV are considered along with the direct intervention inputs, provide much less support for the CCTV Directed Patrol strategy. Modest evidence in support of the intervention was found in the Overall and CJ System models. For the Overall calculations, CBRs suggest significant cost benefits for both the tours (CBR = 2.04) and days (CBR = 1.63) periods. Only the tours period achieved statistical significance (CBR = 1.68) for the CJ System. For Policing, the 11-week period exhibited a significant cost deficit (CBR = 0.45), while

[15] BLS did not provide national salaries for police supervisors. Therefore, we used differences in Newark officer wages to determine national estimates. For example, hourly wages for Sergeants were 13 % higher than Patrol Officers in Newark. Therefore, officer wages were increase by 13 % in the sensitivity analysis to account for Sergeant wages. The same method was used to estimate national wages for Lieutenants and Captains.

findings of the tours and days period did not achieve statistical significance. For both Courts and Corrections, CBRs were well below 1 and statistically significant across all time periods. CBRs ranged from 0.34 to 0.61 for Courts, and from 0.15 to 0.33 for Corrections. This suggests that for any single CJ system component the intervention would be cost prohibitive when CCTV system costs are considered alongside the intervention inputs. Many of CBRs suggest monetary losses of over 50 % for every $1 spent.

Table 6 displays the results of the sensitivity analysis. All significant existing system CBRs in the primary analysis maintained statistical significance in the sensitivity analysis, showing that the cost benefits of the intervention are maintained across both variations of the officer wage calculations. The non-existing system wage variations also produced results similar to the main findings. When officer wages are adjusted, Overall and CJ System calculations exhibited significant CBRs suggestive of a cost benefit for the tours period. For Policing, Courts, and Corrections, all CBRs were statistically significant and suggestive of large cost deficits. While the significance of specific CBRs differed, results were generally the same between the main findings and sensitivity analysis: outside of modest support in the Overall and CJ System calculations, the experimental strategy was largely cost prohibitive in the non-existing system

Table 5 Cost–benefit ratios (*CBR*)

	Existing system		Non-existing system	
Component	CBR	(Lower; upper)	CBR	(Lower; upper)
Overall				
Tours	31.62*	(27.85; 40.19)	2.04*	(1.80; 2.59)
Days	25.35*	(18.44; 37.74)	1.63*	(1.19; 2.43)
11 weeks	19.36*	(6.45; 22.23)	1.25	(0.42; 1.43)
CJ system				
Tours	26.13*	(23.27; 33.04)	1.68*	(1.50; 2.13)
Days	21.02*	(15.33; 31.20)	1.35	(0.99; 2.01)
11 weeks	18.81*	(6.27; 21.60)	1.21	(0.40; 1.39)
Policing				
Tours	14.13*	(12.30; 18.07)	0.91	(0.79; 1.16)
Days	11.43*	(8.54; 16.63)	0.74	(0.55; 1.07)
11 weeks	6.99*	(2.33; 8.02)	0.45*	(0.15; 0.52)
Courts				
Tours	6.83*	(6.48; 8.34)	0.44*	(0.42; 0.54)
Days	5.30*	(3.37; 8.67)	0.34*	(0.22; 0.56)
11 weeks	9.51*	(3.17; 10.92)	0.61*	(0.20; 0.70)
Corrections				
Tours	5.18*	(4.48; 6.63)	0.33*	(0.29; 0.43)
Days	4.18*	(3.12; 6.09)	0.27*	(0.20; 0.39)
11 weeks	2.32	(0.77; 2.66)	0.15*	(0.05; 0.17)

*Statistically significant

calculations. When system costs were reduced by 25 %, both the tours and days period were suggestive of a cost benefit for the Overall and CJ System calculations. Findings for the individual components largely echoed the main results. When system costs were increased by 25 %, CBRs were statistically significant and suggestive of a cost deficit across each time period for Policing, Courts, and Corrections, which concurs with the main study findings. However, both the Overall and CJ System findings were influenced by the increased CCTV system cost estimate. For the CJ System, the lone significant CBR (0.80) suggested a cost deficit over the 11-week period. Conflicting evidence was found in the Overall calculations, with the tours period experiencing a significant cost benefit (CBR = 1.35) while the 11-week period showed evidence of a significant cost deficit (CBR = 0.83). When considered together the sensitivity analyses suggest that findings are largely not influenced by different officer wages or the less expensive CCTV system estimate. However, when CCTV System costs are increased by 25 %, the findings are predominately unsupportive of the experimental strategy.[16]

Discussion

Findings suggest that agencies with pre-existing CCTV infrastructure stand to receive a significant cost benefit from employing the CCTV Directed Patrol strategy. This has implications for Policing, as research has consistently shown the deterrent effect of stand-alone CCTV deployment to be limited. Additional investments may be necessary to make pre-existing CCTV systems effective crime prevention tools. Additional investments have begun to take the form of complementary technologies, such as gunshot-flash recognition and video analytics (La Vigne et al. 2011: 23). Such technologies require extensive funding, and may not assist proactive CCTV activities as expected (for example, see Piza et al. 2014b: 1038). Introducing additional human agents, deployed in a proactive manner, into CCTV operations may be a more cost effective tactic than complimentary technologies. In terms of Policing, the entity most

[16] Since Caplan et al. (2011) found that the first phase of cameras produced a reduction in auto theft, we explored whether a system-wide auto theft reduction may provide the benefit increase necessary to produce a consistent cost benefit. Caplan et al. (2011) found that auto theft reduced by an average of 1.81 incidents (from 7.66 to 5.85) per camera during the first 13 months of the CCTV operation. This translates to an average of 0.03 (1.81/56 weeks) incidents reduced per camera per week. With 32 cameras in the target areas, we estimated that 1.03 (32 x 0.03) auto theft incidents may have reduced per week and that 11.37 (1.03 x 11) auto thefts may have been prevented during the 11-week experiment. We multiplied the estimated auto theft reduction by the costs of motor vehicle theft (converted to 2011 dollars) reported by La Vigne et al. (2011) and McCollister et al. (2010): $6,387.64 in Victim costs, $2,794.72 in Policing costs, $3,802.91 in Court costs, and $1,310.12 in Corrections costs, totaling $7,907.75 in CJ System costs and $14,295.39 in Overall costs. Multiplying these figures by the estimated auto theft reduction produces a cost benefit of $31,775.97 for Policing, $43,239.09 for Courts, $14,896.09 for Corrections, $89,911.12 for the CJ System and an Overall savings of $162,538.58. We compared the auto theft benefits to the Cost Savings Sums presented in Table 3 to determine whether the motor vehicle cost savings could have helped produce a cost benefit for the disaggregate CJ System components. This is a liberal estimate, since we assumed that the estimated auto theft reduction was identical for each of the temporal periods (Tours, Days, and 11 weeks). The estimated auto theft reduction increased the benefits by between 3.34 % (Tours) and 6.75 % (11 weeks) for Policing, between 6.75 % (11 weeks) and 12.11 % (Days) for Courts, and between 4.27 % (Tours), 9.53 % (11 weeks) for Corrections, between 6.35 % (Days) and 7.09 % (11 weeks) for CJ System, and between 7.63 % (tours) and 12.45 % (11 weeks) for the Overall calculations. In each case, these added benefits fall well below the increase needed to covert a cost deficit into a cost benefit.

Table 6 Sensitivity analysis: alternate police officer salaries

Component	Existing system		Non-existing system			
	Officer wages 75th PCTL	Officer wages 50th PCTL	Officer wages 75Tth PCTL	Officer wages 50th PCTL	−25 % CCTV costs	+25 % CCTV costs
Overall						
Tours	38.24*	47.02*	1.58*	1.63*	2.11*	1.35*
Days	30.67*	37.70*	1.26	1.30	1.69*	1.07
11 weeks	23.42*	28.80*	0.97	1.00	1.29	0.83*
CJ system						
Tours	31.61*	38.86*	1.30*	1.34*	1.74*	1.11
Days	25.42*	31.25*	1.05	1.08	1.40*	0.90
11 weeks	22.75*	27.98*	0.94	0.97	1.25	0.80*
Policing						
Tours	17.09*	17.09*	0.70*	0.73*	0.94	0.60*
Days	13.82*	16.99*	0.57*	0.59*	0.76	0.49*
11 weeks	8.45*	10.39*	0.35*	0.36*	0.47*	0.30*
Courts						
Tours	8.26*	10.16*	0.34*	0.35*	0.46*	0.29*
Days	6.41*	7.88*	0.26*	0.27*	0.35*	0.23*
11 weeks	11.50*	14.14*	0.47*	0.49*	0.63*	0.41*
Corrections						
Tours	6.26*	7.69*	0.26*	0.27*	0.35*	0.22*
Days	5.06*	6.22*	0.21*	0.22*	0.28*	0.18*
11 weeks	2.81	3.45*	0.12*	0.12*	0.15*	0.10*

PCTL Percentile; *CCTV* CCTV system cost

*Statistically significant (upper and lower bounds not displayed due to space constraints)

likely to invest in CCTV, the findings suggest that agencies with existing CCTV infrastructure can yield cost benefits between $6.99 and $14.13 for every $1 invested in the CCTV Directed Patrol strategy.

However, the existing system analysis inherently assumes that the agency considers the cost of pre-existing CCTV as somewhat negligible. For certain agencies, this may be the case. In Newark, the NPD paid for the entire CCTV system with funds raised through grants and philanthropy. The allocation of resources towards proactive monitoring and patrol tactics represents a *new* disbursement from the agency's budget, rather than an *additional* disbursement. However, other agencies that allocated internal funds to the installation and maintenance of cameras may not be as willing to ignore their start-up expenses. In this sense, the CCTV Directed Patrol strategy is cost prohibitive for agencies needing to also invest in a CCTV system. Again using Policing as an example, each $1 investment was associated with a loss of $0.55 (CBR = 0.45). While increasing benefits in future implementations of the CCTV Directed Patrol strategy may be possible, expecting the crime prevention capacity to increase so drastically may be unrealistic. It should be noted that minimizing costs might have a similar effect as producing additional benefits. In the extreme, live monitoring functions could be abandoned all together outside of the experimental strategy, meaning no salaries would have to be paid for VSU personnel (see King et al. 2008 for a description of such a passive CCTV operation in San Francisco). Police can also staff VSU entirely with volunteer police officers, given the increased popularity of using volunteer officers in special operations units (Hilal and Olsen 2010). Police may also increase benefits by conducting the CCTV Directed Patrol strategy for a longer period, or strategically targeting crime types not included in the original experiment (e.g., property crime). However, expanding the scope of an intervention does not guarantee increased success, and can actually reduce program effect by creating a treatment group too large to adequately address (Sherman et al. 1989) or by requiring the participation of additional personnel who may not be as capable as the originators (Zedlewski 2009: 358). Nonetheless, the sensitivity analysis demonstrated that reducing CCTV system costs, the most expensive aspect of the experimental strategy, by 25 % failed to generate significant cost benefits for any individual CJ System component. Conversely, increasing CCTV System costs by 25 % generated overwhelming support against the use of the CCTV Directed Patrol strategy. Therefore, we conclude that agencies with existing CCTV infrastructure stand to gain much more from adopting the CCTV Directed Patrol strategy than other agencies. Agencies absent CCTV may want to consider whether funds would be better allocated towards alternate strategies.

This study also suggests the possibility for creating a cost-sharing model across the criminal justice system. Crime reductions generated by the CCTV Directed Patrol strategy, a police-led operation, provided cost benefits for the CJ System. This suggests that governments can consider re-allocating funds to police agencies to offset expenses of crime control strategies when said strategies have the potential to benefit the entire CJ System. Indeed, prior research has demonstrated that shifting resources from imprisonment to police-led crime prevention strategies would greatly enhance crime prevention efforts (Durlauf and Nagin 2011). We recognize that the reduction of one agency's budget to directly increase another's may be a controversial proposition in the current fiscal climate. Thus, we repeat our call for caution from the prior paragraph if a cost sharing model is not feasible.

Conclusion

The current study generated what we consider to be important policy implications for the crime prevention field. Nonetheless this study, like most others, suffers from specific limitations that should be mentioned. First, we were not able to directly measure certain aspects of the intervention inputs and had to generate estimates. This was especially the case with the vehicle fuel costs. This was the result of the post hoc nature of the cost–benefit analysis. Had the cost–benefit analysis been planned as a component of the RCT we could have generated more direct measures. Researchers could have recorded the odometer mileage prior to and following each tour of duty or the NPD could have maintained records of when each vehicle was fueled (and how much fuel was added in each instance). Future research should design cost–benefit analyses in a more ad hoc manner to allow for direct measurement of all relevant expenditures. In addition, we should note that the use of officer wages in intervention cost calculations has been criticized previously. Wayson and Funke (1989) demonstrated that the cost of an officer hour is more than the direct wages when fringe benefits, vacation, sick leave, and supervision are accounted for. However, we feel that our wage calculations are appropriate in this instance. For one, they include fringe benefits, a key concern of Wayson and Funke (1989). In addition, because officers worked on an overtime basis with a direct supervisor, costs associated with vacation, sick leave, and supervision are not as relevant here as in prior research. Furthermore, a recent study used hourly officer wages as a primary measure of police costs (Burgdorf and Kilmer 2015). Nonetheless, we acknowledge criticisms of the officer wage approach.

Furthermore, the concise time frame of the intervention did not allow for a longitudinal analysis for the purpose of determining whether cost effect changed over time. La Vigne et al. (2011) identified that cost benefits in Chicago and Baltimore did not manifest until well after the CCTV systems were installed. In that sense, we may have generated different findings were we able to use a similar analytical method. Furthermore, the CCTV Directed Patrol strategy took place towards the end of the summer months, when crime rates in Newark were at their highest during the pre-experiment period (Piza et al. 2015). The results may have exaggerated the cost benefits generated by the intervention. The results of the cost–benefit analysis employed here could have differed had the CCTV Directed patrol strategy occurred during a different part of the calendar year. The estimates presented likely reflect the maximum cost benefit criminal justice agencies could expect when incorporating directed patrol into their CCTV operations.

Lastly, the crime costs used in this study came from a subset of the extant cost of crime literature. A recent systematic review (Wickramasekera et al. 2015) found 21 studies that estimated crime costs, with considerable variance in the estimates. Incorporating different studies for our cost estimates may have altered our findings. In addition, any limitations present in the prior studies directly influence our findings. A key concern is the use, or lack thereof, of sanction probabilities in cost of crime estimates. The Courts (pre-sentencing) and Corrections (incarceration) costs accounted for the conditional probability of sanction (see La Vigne et al. 2011: 20). For Courts, costs were calculated on a per-minute basis for trials and mean trial lengths for each offense. For Corrections costs, the probability of sentencing, percentage of time served, and facility type (jail vs. prison) were accounted for. Such conditional probabilities were not included in the Policing (arrest) costs (Aos et al. 2001). We acknowledge that the lack of uniform cost methods may have inflated the costs of crime and, therefore, the financial benefits of the experimental strategy. Benefits upwards of \$30 per \$1 of costs have typically not been found in prior cost–benefit analyses (though, Painter and Farrington 2001: 7 claim a benefit of £74 for every £1 spent if the lighting system were paid off over a 20-year period). However, we should note that the intervention inputs (overtime personnel funding and vehicle fueling/maintenance) in this program were much less costly than intervention inputs associated with many of the re-entry and family-focused projects previously subjected to cost–benefit analysis. For example, Multidimensional Treatment Foster Care (MTFC) costs about \$7,400 per family in Washington State (Welsh et al. 2013: 269). The cost of the CCTV Directed Patrol strategy (\$75,861.73) represents the approximate cost of including only 10 families in the MTFC. The high CBRs observed in the current study may be related to the less expensive intervention inputs as well as the costing methods employed. Indeed, CBR values were much lower when accounting for the cost of the CCTV system, which brings intervention input expenses more in line with prior research.

While acknowledging these limitations, we believe that this study positively contributes to the crime prevention literature. This study adds a cost–benefit analysis to the CCTV literature while introducing the approach of disaggregating cost savings according to the CJ system component that would directly benefit. Conducting cost–benefit analysis in such a manner has direct implications for policy makers considering the adoption of new strategies, and can be used in the evaluation of crime prevention interventions outside of CCTV.

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